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ABSTRACT

Characteristics of 292 youths (269 males and 23 females) identified by high scores (before the age of 13) on the Scholastic Aptitude Test-Mathematics as part of the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University are reported. Several of the students have received Ph.D. degrees at very young ages. The young students also scored substantially higher on the verbal section of the SAT and the Test of Standard Written English than did average college bound high school seniors. More variability was found among male high scorers. Two students were Black, 22% were of Asian parentage. Parents of the group were well educated averaging a master's degree for fathers and a bachelor's degree for mothers. Paternal occupational status was consistent with educational level. Seventy percent of the girls and 63 percent of the boys were the oldest in their families, with 17 percent of the girls and 11 percent of the boys being only children. Most of the students had accelerated grade placement by the end of high school and college. An appendix describes procedures for participating in the ongoing talent search. (DB)

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Abstract

For the first time, statistics concerning background characteristics of this remarkable group of 292 youths who reason extremely well mathematically are presented. Identified initially at age 12 or less, they reside all over the United States. The sex ratio is 269:23. They tend to be quite able verbally, but much more so mathematically. Most of their parents are well educated. Some of these young students are vastly more accelerated in school grade placement than are the majority of the group. Other relevant characteristics are also discussed.

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Some Characteristics of SMPY's "700-800 on SAT-M Before Age 13" Group¹

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Since 1971 we of the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University have been studying the characteristics of boys and girls who, in annual talent searches, at age 12 or younger score well on the mathematical sections of the College Board's Scholastic Aptitude Test (SAT-M). Most of these are in the middle of the seventh grade when they take all three parts of the SAT: mathematical, verbal, and Test of Standard Written English (TSWE assesses proficiency in the mechanics of English expression). Experience by us and others with many thousands of examinees has shown that SAT-M is an excellent measure of mathematical reasoning ability for youngsters, rather than primarily of computational facility or ability to learn concepts and algorithms taught systematically (e.g., Angoff, 1971; Benbow & Stanley, 1983; Minor & Benbow, submitted). This ability seems to be crucial for learning precalculus mathematics, first-year college calculus, physics, and a number of other quantitatively oriented subjects readily and well.

Eligibles for the 12 annual talent searches thus far have usually been seventh graders of any age who on an in-school achievement test battery have scored in the top 3 percent of national norms on the mathematical or verbal part, or overall. Before 1980, SMPY conducted the annual Johns Hopkins talent search and used only the mathematical criterion. Eligibility via verbal or total scores began in 1980, after the Center for the Advancement of Academically Talented Youth (CTY) was formed at Johns Hopkins to conduct

talent searches and special educational programs. Though instrumental in getting CTY started, SMPY has always been wholly independent of it. CTY's Director is Dr. William G. Durden. The number of students reporting SAT scores in the Johns Hopkins talent search rose from its low of 450 in 1972 to approximately 24,000 in 1986 (CTY, 1986).

500-800 or 700-800 on SAT-M Before Age 13

About 18 percent of the boys and 9 percent of the girls in a talent search score 500 or more on SAT-M before age 13; we estimate that they are the top 1 percent of their age group with respect to mathematical reasoning ability. The average college-bound male high-school senior scores 499, the average such female 452 (College Board, 1985).

We consider a youth as being exceptionally talented quantitatively if he or she scores at least 500 on SAT-M before age 13, but the score scale runs much higher, to 800. About 6 percent of college-bound male twelfth-graders score 700 or more, and less than 2 percent of college-bound female twelfth-graders. To score 700 or more on SAT-M before age 13 seems a phenomenal feat, rarely to be accomplished by almost anyone because the youth is not likely to have studied much mathematics in school yet. Even in SMPY's small first talent search in 1972, however, two of the students scored above 700. There were some 700-800M scorers in each subsequent talent search, about 12 times as many males as females (Benbow & Stanley, 1983).

These observations led to a systematic national three-year search to create a special "700-800 on SAT-M Before Age 13" group to be helped educationally and studied. We used the November 1980 through October 1983 administrations of the SAT across the country by the Educational Testing Service as the time framework in which to search for >700M boys and girls born not earlier than 1968. About half of the qualifying youths whom we located

came through CTY's annual talent search, the Midwest Talent Search conducted by Joyce VanTassel Baska from Northwestern University, searches in Illinois conducted by Sandra Schmulbach, the Project for the Study of Academic Precocity search of the West conducted by Sanford J. Cohn from Arizona State University, and the Talent Identification Project conducted by Robert N. Sawyer from Duke University. The other half came directly to our attention via various types of publicity the search attracted--in newspapers, magazines, and by word-of-mouth.

We found 269 boys and 23 girls. They now reside in 30 states, the District of Columbia, Canada, and Guatemala, as follows: California (44); Maryland (42); New Jersey (37); New York (26); Michigan and Pennsylvania (20 each); Virginia (16); Illinois (15); Ohio (12); Arizona and Massachusetts (7 each); Connecticut and Washington (5 each); Delaware and Kansas (4 each); Indiana, North Carolina, Tennessee, and Wisconsin (3 each); Oregon and Texas (2 each); and 1 each for Alabama, Alaska, Canada, D.C., Florida, Georgia, Guatemala, Hawaii, Iowa, Maine, Missouri, and New Hampshire.

We know that this type of search, which is continuing,² does not uncover nearly all the persons who would have qualified if they had taken the SAT-M young enough. Our best estimate from several converging lines of evidence is that about 1 in 10,000 12-year-olds could qualify. At this rate, fewer than 400 are born each year in the United States. Thus, with respect to mathematical reasoning ability these are the top one-hundredth of 1 percent of that age group, undoubtedly the most quantitatively apt set of youngsters ever identified. If other abilities and their environmental influences are favorable, these young students seem to have the potential to become the nation's superstars in pure and applied mathematics, computer science, electrical engineering, physics, and other fields that depend heavily on great quantitative aptitude. Quite a few of the 292 appear well on the way toward .

excellence in such fields.

Also, we know the accomplishments thus far of some 700M scorers from earlier talent searching. For example, the first two, from the 1972 talent search, received Ph.D. degrees at age 24, one in computer science from Cornell University and the other in applied mathematics from the Massachusetts Institute of Technology. Two from that first search who scored a little below 700 also received Ph.D. degrees at age 24, in computer science and theoretical plasma physics, respectively, from two of the country's greatest universities.

Other Characteristics of the 700-800M Group

After that general background, let us go to certain statistics that describe the group better. All of the qualifiers scored at least 700 on SAT-M before age 13, or had to earn an additional 10 points for each month or fraction of a month he or she was beyond the 13th birthday when tested. The average age of the boys when they qualified on SAT-M was 12.5 (s.d. 0.59). For the girls these statistics were 12.7 and 0.64.

What were the means and standard deviations of the two sexes on SAT-M, SAT-V, and TSWE? These are shown in Table 1. It is clear that these students are more

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precocious mathematically than verbally. Even on SAT-V and TSWE, however, they scored far beyond the average college-bound high-school senior of their sex, being for both sexes on both tests in the upper fourth or fifth of that norm group. The girls scored higher than the boys on each of the three parts of SAT: 5 points on M, 15 points on V, and the equivalent of 31 points on TSWE.

The two sexes had equally variable M and V scores, but the boys were far more variable on TSWE; the ratio of those variances was almost 2 to 1. No girl scored less than 40 on TSWE, whereas 8 percent of the boys did. Similarly, 30 percent of the girls but only 16 percent of boys earned the highest possible score, 60, on TSWE. Clearly, these girls tend to be more careful with commas, capitalization, tense and number of verbs, etc. than these boys.

Mediation of M Via V or RPM?

The huge standard deviations of the SAT-V scores, 94 for the boys and 93 for the girls, suggest that explicit selection on SAT-M restricts the range of verbal ability little or none. For comparison, in CTY's annual talent search the typical standard deviation of SAT-V scores is approximately 78 (CTY, 1986). Even the variance of the College Board's SAT population for the entire country over several forms of SAT-V during a given year is only 42 percent greater for males and 37 percent greater for females than the variances of the V-scores of these high-M youths.

The discrepancy for a given individual can be large. One of SMPY's best mathematics students scored 760M and 310V at age 12 the second time he took the SAT, a 3.5-standard-deviation discrepancy. The eight-year-old in Australia scored 760M and 290V. A year later his V-score had risen to 380, still 134 points less than the mean for boys shown in Table 1. At that rate of increase, however, he would approach Harvard's average at age 12 and score 800 by age 14 (Stanley, in press).

A 12-year-old scored 720M and 750V. He was a much slower learner of mathematics than the 760M 310V 12-year-old. It seems likely that there is a "hidden variable" essential for learning mathematics from algebra through elementary calculus fast and comfortably at an early age. Sheer high IQ alone

is not sufficient. Non-verbal reasoning ability of the sort measured by the advanced (36-item) form of the Raven Progressive Matrices (R) seems essential.

For example, the 380V Australian 9-year-old scored 32 points on R in about 45 minutes; the average British university student scores 21. Also, the boy did not miss any of the 4 most difficult items, and quickly corrected his four errors when told which of the 8-option items he had marked incorrectly.

Thus, in assessing the cognitive abilities of a mathematically highly precocious youth one needs to know at least his or her M, V, and R scores. All three may be high, or M and V may be high and Raven fairly low. It is unlikely that M will be extremely high but both V and R extremely low. Either good verbal or good Raven ability appears needed to produce a high-M scorer at an early age.

This triadic relationship, which seems to imply crystallized vs. fluid intelligence (e.g., Horn, 1976), is chiefly conjecture at present. SMPY's researchers have not yet administered the advanced form of the Raven Progressive Matrices to enough high-M high-V vs. high-M low-V scorers to be sure the hypothesis holds up. I believe it warrants further study.

Other Characteristics

The 292 vary greatly in ethnicity and national origin. Two are black males. Twenty-two percent are of Asian parentage, chiefly Chinese and mostly first-generation Americans, compared with the 1.6 percent of Asian Americans in the U.S. (Moore & Stanley, unpublished). Parents of the group are well educated, averaging about a master's degree for the fathers and a bachelor's degree for the mothers. The fathers have nearly 3 1/2 times as many doctorates as the mothers. The girls' parents have 75 percent more doctorates than the boys'. See Table 2 for further details.

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The fathers' occupational status runs the gamut from quite low to extremely high, but is consistent with their average educational level. Neither it nor the mothers' differs much according to the sex of their child.

Parents had married rather assortatively. The educational level of the boys' parents correlated .58, exactly the same figure that Benbow and Stanley (1980) found for the 873 participants in SMPY's 1976 talent search. It was .50 for the parents of a comparison group of 92 participants in the talent searches who had scored at virtually the chance level on both M and V (personal communication from Camilla P. Benbow). For the 23 700M girls of the present study parents' education correlated .77, not significantly different statistically from the boys' .58.

Of the six possible correlation coefficients among the three SAT scores for the two sexes, only the two for V with TSWE were of appreciable magnitude: .61 for boys and .83 for girls. The explicit restriction of range on M kept its correlations with V and TSWE low.

None of the three SAT scores related substantially to father's or mother's education level or occupational status. By the way they had been selected for the "700-800 on SAT-M Before Age 13" group, all 292 youths had extremely high mathematical reasoning ability, no matter what their parents' education and occupation might be. Nevertheless, the lack of correlation of education and occupation with V and TSWE is surprising. For the 507 boys and 366 girls in the 1976 talent search, Benbow & Stanley (1980) found 12 r s ranging from .14 to .34 (median, .25) for the 2 x 2 x 3 matrix of correlations of SAT-M and SAT-V scores with the father's education, mother's education, and father's occupational status. They had no TSWE scores.

Age at time of qualifying on SAT-M correlated for the boys modestly but beyond the .05 level of statistical significance with SAT-M score (.14), SAT-V score (.21), and TSWE score (.14), but non-significantly with father's education (-.08) and mother's education (-.08). Because of the small number of girls their respective rs (.20, .09, .00, -.11, and -.04) were not statistically significant.

Siblings

The girls averaged having 1.2 siblings; 17 percent of them were only children. Seventy percent were the oldest. The boys averaged having 1.4 siblings; 11 percent were only children. Sixty-three percent were the oldest. Thus, no sizable sex differences in the sibling relationships were found.

Educational Acceleration

Over the years we have learned that youths who score extremely high on SAT-M tend to accelerate their grade placement in school considerably by the end of high school and college. In this study of the background of these students as they qualified for the 700-800M group it is natural to wonder whether or not they were already appreciably accelerated when first identified. Although they were then the age of not more than seventh graders, we found that 48 percent of the boys and 65 percent of the girls were above that grade level. The mode for the boys was seventh grade; for the girls it was eighth grade. It is not clear to what extent high test ability caused the acceleration. Instead, acceleration into higher subject matter may have increased the score. This is the familiar confounding of cause and effect.

A few of each sex were in the highest category, "Beyond 11th grade." For example, one boy received his bachelor's degree in mathematics, with high honors, at age 12 years 42 days. Another received his in mathematics before

his 14th birthday.

When found, no girl was enrolled below the seventh grade, whereas 6 percent of the boys were in Grade 6 and one boy was in Grade 5. Imagine how an elementary school teacher must feel to have in his or her fifth-grade class a youngster who scores as high on SAT-M as the average Harvard freshman did at age 17 or 18! Would anyone expect such a teacher to be able to individualize instruction in mathematics sufficiently for that mathematically gifted a student?

The record score we have found is 760 on SAT-M at age 8 the first time SAT was taken by a Chinese-background boy, Terry Tao, in Australia. A 7-year-old in California, also of Chinese ancestry, scored 670 his first try. Fortunately, both of these boys were allowed to move ahead much faster in mathematics than their agemates. Terry, now 10, is in sophomore mathematics and freshman physics at a university while remaining in high school for other subjects. He is a member of Australia's six-person high-school team for the International Mathematical Olympiad this year, having barely missed being on it at age 9!

Conclusion

Much can, and should, be done for youths this able. For 15 years SMPY has been busily devising various educational procedures that vastly improve curricular flexibility and articulation of one level of a subject with the next. For example, young students learn much mathematics, biology, chemistry, physics, computer science, or other subjects in three or six summer weeks (see Benbow & Stanley, 1983a, and Stanley & Stanley, 1986). We are cheered by our successes, and spurred on to greater efforts by the many obstacles that the age-in-grade Carnegie Unit lock step puts in the way of individualizing instruction.³

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Footnotes

¹Paper read at the annual meeting of the American Educational Research Association in San Francisco on 18 April 1986. I thank Camilla P. Benbow, Linda E. Brody, Christine M. Penn, and Barbara S. K. Stanley for help in preparing it.

²Please see the Appendix for an explanation of eligibility rules.

³For details about the rationale of SMPY, see Stanley and Benbow (in press). For an extension to the People's Republic of China, see Stanley, Huang, & Zu (in press).

Table 1
SAT Scores of the 700-800M Group

Gender	SAT-M			SAT-V			TSWE		
	Mean	%ile [*]	S.D.	Mean	%ile [*]	S.D.	Mean	%ile [*]	S.D.
Male	730	97	26	514	75	94	51.5	76	7.9
Female	735	99	26	529	82	93	54.6	82	5.8

^{*}Percentile rank of mean for same-sex college-bound high-school seniors
(College Board, 1985)

Table 2

Educational Level of Parents of the 700-800M Group (Percentages)

<u>Level</u>	<u>Father of</u>		<u>Mother of</u>	
	<u>Boys</u>	<u>Girls</u>	<u>Boys</u>	<u>Girls</u>
Doctorate or equivalent	43	74	12	22
Master's degree	19	17	24	43
Bachelor's degree	25	4	40	22
Two-year degree	1	0	5	4
Some college	5	0	9	4
Technical school	1-	4	3	0
High school graduate	3	0	5	4
Less than high school	1-	0	1	0
Not ascertainable	3	0	2	0
N	269	23	269	23

APPENDIX

SEARCH UNDER WAY FOR YOUTHS EXCEPTIONALLY TALENTED MATHEMATICALLY

SMPY conducts nationwide searches for the tiny fraction of youngsters 12 and under who demonstrate extraordinary mathematical reasoning ability.

The talent search--"700-800 on SAT-M Before Age 13" on the mathematical (M) part of the College Board's Scholastic Aptitude Test (SAT)--is designed to identify mathematically highly talented students and to help them enrich their educations. SMPY sends members of the group materials suggesting how they can proceed faster and better in mathematics and related subjects. Also, from time to time SMPY obtains scholarships for pre-college summer experiences.

Julian C. Stanley, professor of psychology and director of the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins, and Camilla P. Benbow, now an associate professor of psychology at Iowa State University, instituted "700-800 on SAT-M Before Age 13" in the fall of 1980. During its first three years the search located nearly 300 boys and girls throughout the United States who scored at least 700 (attained by only the upper 6 percent of college-bound 12th grade males) on the mathematics portion of the College Board's Scholastic Aptitude Test (SAT-M) before the age of 13.

A graduated scoring system permits students to be eligible beyond their 13th birthday. After his or her 13th birthday, a student participating in "700-800M Before Age 13" must earn ten points above 700 for each month or fraction of a month, up to the maximum attainable score of 800 the day he or she becomes 13 years 10 months old.

Boys and girls who want to qualify for the 700M group should take the entire SAT--that is, the mathematics and verbal portions as well as the Test of Standard Written English--in their communities on a regularly scheduled testing date. A free practice booklet ("Taking the SAT") and SAT registration materials may be secured from the college counselor in any senior high school or by writing the Educational Testing Service, Princeton, New Jersey 08541. Those intending to take

the SAT examination should study the first half of the practice booklet thoroughly and then take its practice test under timed conditions. For more practice, send \$8.95 to ETS for a 300-page book entitled Ten SATs.

Students who qualify should send a copy of their SAT score report to Professor Julian C. Stanley, SMPY, 30 Shriver Hall, Johns Hopkins University, Baltimore, MD 21218.

About the Author

Julian C. Stanley is a professor of psychology at Johns Hopkins University in Baltimore and the Director of the Study of Mathematically Precocious Youth (SMPY) there. He is a past president of the American Educational Research Association, the National Council on Measurement in Education, and the Divisions of the Educational Psychology and of Evaluation and Measurement of the American Psychological Association. His latest book, co-edited with Camilla P. Benbow, was Academic Precocity: Aspects of Its Development (Johns Hopkins University Press, Baltimore, MD 21218, 1983).

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